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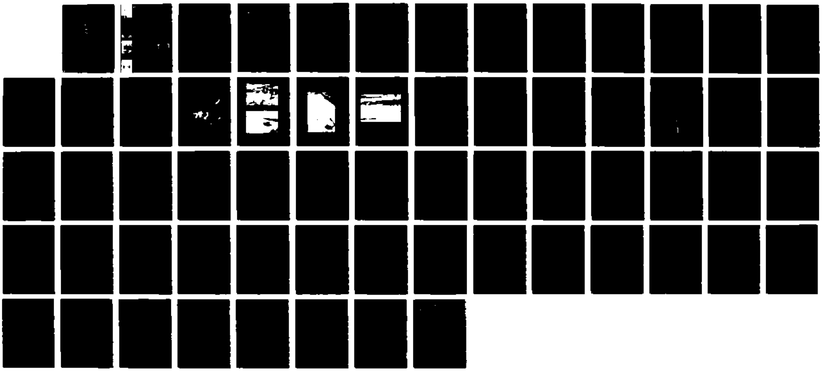

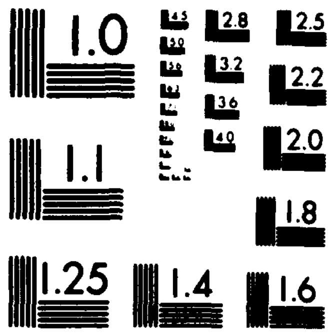

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ENVIRONMENTAL IMPACT RESEARCH PROGRAM

TECHNICAL REPORT EL-87-8

TRANSPLANTING OF THE SEAGRASSES *HALODULE WRIGHTII*, *SYRINGODIUM FILIFORME*, AND *THALASSIA TESTUDINUM* FOR SEDIMENT STABILIZATION AND HABITAT DEVELOPMENT IN THE SOUTHEAST REGION OF THE UNITED STATES

by

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19 ABSTRACT (Continue on reverse if necessary and identify by block number)

Little information is available on the population growth and areal coverage rates of the tropical and subtropical seagrasses shoalgrass, manatee grass, and turtlegrass. However, such data are needed to manage restoration of these systems. In this study, seagrass transplants were conducted at sites across a broad geographic area in order to assess seagrass shoot generation and coverage rates under different environmental conditions. The environmental factors considered were temperature; salinity; light attenuation; water depth; hydraulic regime; sediment type, fluctuation, and depth; and biotic disturbance. Of these factors, temperature, sediment fluctuation, sediment depth, and biotic disturbance were seen to affect transplants. Biotic factors were probably most influential in transplant survival and coverage through shading, temperature increases due to reduced circulation, excavation, and grazing.

Shoot generation and coverage rates were determined for south Florida and the
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northeast Gulf of Mexico. Shoot generation rates varied as a function of species, planting season, and geographic (latitudinal) location. Shoot generation rates for the three species were ranked as shoalgrass > manatee grass > turtlegrass, although differences were less pronounced in the northeast Gulf sites than in the south Florida sites. These data are expected to be transferable at similar latitudes within the distribution of the species.

Transplant stock for shoalgrass and manatee grass should contain rhizome apical meristems and can be dug from donor meadows in areas protected from waves and strong currents. These species also sometimes exhibit a stoloniferous-like growth which, when removed from the parent plant, is highly suitable for transplanting. Wrack-line collections of planting stock are also recommended. Transplanting stock for turtlegrass should be either sprigs with rhizome apical meristems (taken from meadows salvaged from dredging or filling) or seeds and seedlings. Natural turtlegrass meadows should be used for sprig collection only as a last resort.

Shoalgrass and manatee grass should be established first and followed with sprigs or seedlings of turtlegrass after the first seagrasses have coalesced. Attempting to use the slower growing turtlegrass as the *primary* transplant species could be 30 to 90 times more costly than using the other species over the same time span. Plantings should be considered successful if surviving planting units exhibit a coverage rate similar to data presented here, if the coverage generated equals or exceeds the impacted meadow acreage, and if that coverage persists through time.

PREFACE

This report was sponsored by the Office, Chief of Engineers (OCE), US Army, as a part of the Environmental Impact Research Program (EIRP), Work Unit 31632, entitled Coastal Erosion Control Techniques Using Plants. The Technical Monitors for the study were Dr. John Bushman and Mr. Earl Eiker of OCE and Mr. David B. Mathis, Water Resources Support Center.

The study and preparation of a draft final report were accomplished during the time period 1 October 1982 to 1 October 1983; preparation of the reproducible copy was done during August 1986.

The report was prepared by Mark S. Fonseca, W. Judson Kenworthy, and Gordon W. Thayer of the Southeast Fisheries Center, Beaufort Laboratory, Division of Estuarine and Coastal Ecology, National Marine Fisheries Service, under Support Agreement W74-RDV CERC 81-40.

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COL Allen F. Grum, USA, was the previous Director of WES. COL Dwayne G. Lee, CE, is the present Commander and Director. Dr. Robert W. Whalin is Technical Director.

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CONTENTS

TRANSPLANTING OF THE SEAGRASSES *HALODULE WRIGHTTI, SYRINGODIUM FILIFORME,* AND *THALASSIA TESTUDINUM* FOR SEDIMENT STABILIZATION AND HABITAT DEVELOPMENT IN THE SOUTHEAST REGION OF THE UNITED STATES

PART I: INTRODUCTION

The Problem

1. Seagrass systems are among the most productive plant communities on the planet (McRoy and McMillan 1977, Zieman and Wetzel 1980). Seagrass meadows are the primary habitat for a significant portion of recreational and commercially valuable fishery organisms during part, if not all, of these organisms' life histories (Petersen 1918, Thayer et al. 1975). Some impact to this valuable habitat is unavoidable, given our needs for recreation, commerce, and defense. Physical displacement of seagrasses is probably the most redressable form of perturbation to these systems. No form of restoration, however, can prevent a net loss of productivity due to displacement of the associated and dependent fauna. This report describes research concerning the restoration of subtropical seagrass habitats for the recovery of fishery organisms.

2. A more insidious form of seagrass loss is the result of diminished water quality. Die-off of seagrasses due to waterborne changes in environmental conditions, especially those involving decreased light penetration into the water column, elicit a negative trend that is difficult to detect or reverse (Wetzel and Penhale 1983). When light energy transmission becomes insufficient so as to halt photosynthesis by the seagrasses, widespread mortality of the shoots often occurs. When the meristem of the seagrass dies, decomposition of foliar and subsurface portions rapidly occurs (within several weeks). Lacking the protective buffer of the seagrass canopy and the binding action of the root-rhizome system, sediments are prone to erosion and suspension, exacerbating the light penetration problem. Reestablishment of seagrasses into such areas is ultimately very expensive (if even possible), and probably more expensive (to the public) than having prevented the water quality deterioration in the first place. Prevention can be difficult if the causes of poor water quality are nonpoint sources, either anthropogenic or natural in origin. Thus, restoration of such areas should not be addressed solely by replanting vegetation. For the above

situation, an increase in water quality must occur so that the seagrasses can survive long enough to aid in removing sediment from the water column and, thus, further decrease turbidity.

3. There are few areas in the coastal zone that are presently devoid of seagrasses where these plants may be quickly and successfully introduced. This was pointed out a decade ago by Ranwell et al. (1974) in regard to Great Britain and is just as true for the Western Hemisphere today. The problem can be distilled into a simple postulate:

> Lack of seagrasses in a given area suggests environmental conditions unsuitable for their growth.

While this may appear to be simple and straightforward reasoning, it is regularly overlooked or ignored in selection of transplanting sites.

4. The general lack of suitable, transplantable sites dictates conservation of existing meadows in lieu of transplanting into areas that either cannot support seagrass growth or have existing seagrass cover with unvegetated spaces intermixed. Natural seagrass systems (or systems of any other species) have and maintain an ambient level of patchiness that cannot be decreased through simple transplant additions to those spaces unless the environmental regime itself is changed. In this report, regime refers to the local, time-averaged interaction of water motion, temperature, salinity, light, nutrients, and biotic community interactions.

5. Another important point argues for conservation of these systems. The simple fact is that no information exists which adequately answers the question "do artificially propagated meadows function as natural, undisturbed ones and, if so, how long does that take to develop?" As stated by Race (in press) in reference to salt marshes, "with this loss in mind, a mitigation site should be viewed not simply as a man-made or restored marsh (sensu seagrass meadow), but as a permanent substitute for a sacrificed area," a statement that applies perfectly to the concept of mitigation in seagrass systems. Our point here is that since we do not know what the value of restored seagrass meadows may be in comparison to natural ones, conservation should be given high management priority.

6. The scope of application of this report is technically limited to the immediate geographic areas of the test plots. However, the authors are

confident that these results, when prevailing environmental conditions are taken into account, can be extrapolated across the distribution of the species studied. Growth rate data on many experimental plots over a wide geographic area are presented in an attempt to convey the amount of variability one should expect in employing this technology across geographic areas. As more applications of this information are made, new and innovative approaches to the problem are expected. The authors encourage input from persons with ideas and suggestions regarding the technology presented herein. It is imperative to expand the data base on this important aspect of habitat restoration.

Information Synthesis

7. The thrust of this study was to combine existing information on subtropical *Halodule wrightii* (shoalgrass), *Syringodium filiforme* (manatee grass), and *Thalassia testudinum* (turtlegrass) ecosystems with our own studies regarding reestablishment of these beds. There has been much research on the biology, physiology and production ecology of seagrasses, including the environmental conditions under which they exist. In all these studies, however, virtually nothing had been done regarding the population ecology of the plants, except in assessments of sexual reproduction by the plants (Churchill and Riner 1978; Churchill 1983; Silberhorn, Orth, and Moore 1983).

8. Bak (1980), Orth and Moore (1983), and Phillips, Grant and McCoy (1983) studied populations of eelgrass at various ages and made estimates of branching (asexual reproduction). Riner (1976), Kenworthy et al. (1980), and Fonseca et al. (1985 a,b) have performed perhaps the best controlled transplant experiments to date with actual population growth information. However, aside from these works, early work by Setchell (1929) on branching of eelgrass, and inferences from papers by den Hartog (1971), Patriquin (1975), and Zieman (1975), there have been no further quantitative estimates of asexual reproduction by seagrasses.

9. Asexual reproduction, or new shoot generation, is of central importance in transplanting studies. By this form of reproduction, shoots spread out via rhizomatic development as branches from parent shoot/rhizome assemblages. This method is more valuable to the transplants than natural seedling recruitment (the result of sexual reproduction), which is very irregular by year and site (Fonseca et al. 1985b). Therefore, the studies

reported herein were not concerned with productivity and standing stock (biomass); rather, the work focused on assessments of new shoot generation rates while controlling for seedling and whole-shoot (drift material) recruitment.

PART II: ENVIRONMENTAL PARAMETERS

Site Selection

10. The sites in the northeast Gulf of Mexico and south Florida that were selected for study had been recently dredged or had formed from recently deposited dredged material. Since it was not always possible to find sufficient sites, we also planted in undisturbed, unvegetated spaces among existing meadows. The authors were of the opinion that population growth was not significantly affected by planting in unvegetated spaces as opposed to dredged material that has been lying for several months. Differences might be expected when planting in very recently disturbed sediments (Kenworthy and Fonseca 1977). Only in south Florida were plants placed on sites that had been uncovered for weeks instead of months. The rapid population growth of the plantings (complete cover in as little as 160 days) did not suggest that any adverse effects occurred.

11. The selection of sites within geographic areas was done so as to locate sites influenced by different environmental conditions. In order to assess population growth as a function of environmental conditions, we periodically monitored light, temperature, salinity, sediment movement, and sediment quality (texture and organic matter content). A high frequency of monitoring at most sites was not logistically feasible given the geographic distance between the study areas and the base laboratory.

Northeast Gulf Study Sites (Panama City, Florida)

Location and dimensions

12. Both study sites were located in St. Andrews Bay, near Panama City and Panama City Beach (Figure 1). One site, near Redfish Point (henceforth called Redfish site or Site A, Figure 1) was located on the west side of Smack Bayou, a quiescent backwater fringed by marsh. Large, semiconical depressions down to 4 m in depth were found with substantial unvegetated subtidal sand areas in between. The presence of large fragments of metal, surrounding seagrass cover at greater and lesser depths, and the location of the site being immediately adjacent to a military installation led to the speculation that their origin was due to high-explosive detonations. Their configuration was strikingly similar to other sites so impacted (M.S. Fonseca and W.J. Kenworthy, pers. observ.).

13. The other site (Treasure Island, Site B) was located on an old (>2 years) dredged material island 300 m east of the bridge which bisects Grand Lagoon (Figure 1). The approximate longitude and latitude for these sites are 85°40'W and 30°10'N., respectively. Dimensions of individual planting plots are given in Table 1.

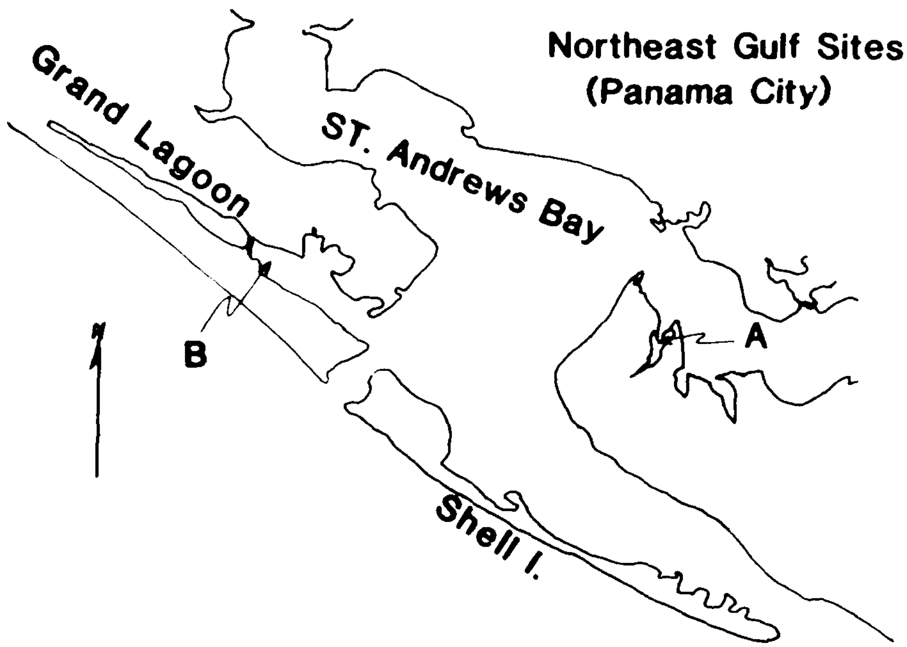

Figure 1. Map of St. Andrews Bay showing location of Northeast Gulf study sites (Panama City) (Site A = Redfish Point, B = Treasure Island)

Bathymetry

14. Bathymetry of both sites was determined relative to the water surface during each sampling period (Table 2). The values are given as average depths. The sites were arranged down slopes corresponding to the vertical distribution of adjacent meadows in an attempt to integrate the overall response of growth across depth gradients in that area.

Light

15. A Sea Tech 25-cm transmissometer was used to measure light transmission. Because of the travel distances involved, readings were taken only during regular site visits and independent of weather conditions. Data were recorded as attenuation coefficients (k) for each site. Fluctuations in k are strongly controlled by local wind and rainfall conditions. The nature

and frequency of these wind and rain events are generally unpredictable, and no coherent pattern of k as a result of these factors, was evident on the time scale sampled. Therefore, data were reduced to average yearly values.

16. To compare the planting sites on a light energy basis, average depth Z and average yearly attenuation k were used in the following equation:

$$I_{(Z)} = I_{(o)}e^{-kZ} \quad (1)$$

where
$I_{(Z)}$ = light at depth (Z)
$I_{(o)}$ = incident light at sea surface
k = attenuation coefficient

Given that $I_{(o)}$ = photosynthetically active radiation (PAR), the value determined by e^{-kZ} (a value between 0 and 1.0) is a factor by which incident light is reduced as a function of attenuation and depth. The value $e^{-kZ} \times 100$ is estimated to be the average annual percentage of incident light available at the sediment surface of each site (Table 2).

Temperature and salinity

17. These parameters were recorded during site visits using a glass thermometer and refractometer, respectively. Readings were taken at the mid-depth level in the water column. Temperatures ranged from 19.5° C in April (1984) to 28° C in August ($\bar{X}$ = 24.7° C +/-4.3, standard deviation) at Redfish and 19.5° to 30°C ($\bar{X}$ = 25.5° C +/-4.9) at Treasure Island. Salinities ranged between 17 and 20 o/oo ($\bar{X}$ = 18.5 o/oo) at Redfish versus 24 to 28 o/oo ($\bar{X}$ = 26 o/oo) at Treasure Island.

Hydrodynamic regime

18. Current velocities. Current velocity was measured by propeller-type flowmeters. Readings were taken for 2 to 4 hr during selected site visits. Velocities at both sites ranged between 2 and 4 cm/sec.

19.' Fetch. Both sites had similar fetches of approximately 0.3 km. These are relatively low wave energy sites. The Treasure Island site is adjacent to a channel serving a marina and experiences 0.5- to 1.0-m wave heights from periodic boat traffic. When tides are low, these boat wakes were observed to cause substantial sediment movement in the study area.

Sediment characteristics

20. Surface sediment samples were collected by divers using plastic cups that scraped the top 1 cm of sediment and were immediately capped under water to prevent loss of fine particles. Three replicate samples were arbitrarily taken from between planting units at each site. The sediment samples were placed in a drying oven at 90^{0} C and allowed to dry to a constant weight. After drying, each sample was either pulverized in an electric pulverizer for 20 min or ground in a mortar and pestle to ensure that particles consolidated by the drying process were disaggregated. Samples then were sieved in a sediment shaker for a 20-min period, using a standard sieve mesh series. Contents of each sieve were weighed to the nearest 0.1 mg. Particle-size distributions in each sample were characterized using the phi notations of Inman (1952). Phi mean, phi deviation, skewness, and kurtosis were calculated by the statistical techniques of Folk and Ward (1957). Two subsamples were obtained from each sample prior to sieving, with percent organic matter of each determined by combustion at 500^{0} C for 24 hr.

21. The sediments at both sites were quite similar and remained so during the study (Table 3). The mean phi range was medium to mostly fine sand on the Wentworth scale. The sediments were all well sorted with a nearly symmetrical distribution at Redfish versus a slightly negative skewness (toward coarseness) at Treasure Island. These nearly symmetrical tendencies are reflected in the relatively mesokurtic Ki values. The percentage of organic matter was extraordinarily low for such relatively quiescent areas (<1.0 percent). Both sites had virtually no silt-clay in the sediments (<0.1 percent). The possible origin of the Redfish site from explosive detonations could explain these low values as could the wave scour from boat traffic at the Treasure Island site.

Sediment flux rate and sediment depth

22. Sediment fluctuation rate was sampled relative to boundary stakes around the sites which served as common datums. The absolute value of sediment fluctuation during the first 45 days was 0.07 cm/day at Redfish versus 0.139 cm/day at Treasure Island. The mean (130 days) was 0.046 cm/day at Redfish versus 0.102 cm/day at Treasure Island. These are very moderate rates as described by Fonseca et al. (1985b) and could explain some of the planting unit loss: 57 percent of planting units remaining at Redfish, 41 percent at Treasure Island.

23. Sediment depth to consolidated substrata was measured by driving a steel rod into the sediment with a 3-lb (1.4-kg) sledge hammer to 1.5 m. No consolidated substrata were encountered at either site.

Effects of biota on transplants

24. Grazing by pinfish (*Lagodon rhomboides*) at both sites was considerble. Both manatee grass and shoalgrass plantings were grazed back to short nubs, which may have damaged the apical meristems, affecting population growth of the plantings. In comparison to Beaufort, N.C., and some south Florida sites, however, this grazing was limited to individual planting units and was not uniform over the transplant. Grazing was haphazard, and no visual or positional clues were obvious that could help formulate a pattern of grazing. Burrowing also was observed at these sites and was very heavy at the Redfish site, resulting in the loss of many planting units. Rays or crabs were likely responsible, since many broken shells were found in the 1-m-wide pits that were frequently observed across the site.

South Florida Study Sites (Florida Keys)

Location and dimensions

25. All study sites were located in Monroe County (Florida Keys), Fla. (Figure 2). The four sites from north to south were: Rock Harbor (Site A), Channel 5 (Site B), Boog Powell Marina (Site C), and Stock Island (Site D) (Figure 2). Each site was substantially different from the others, and all are described below. Experimental transplant dimensions for each site are given in Table 4.

26. Rock Harbor. This site was located on Key Largo on a spit removal site in the northeast end of Lake Largo (Figure 2). An illegal road had been built through subtidal habitat among red mangroves for fill removal access. The road was removed in 1982, and the area was returned to the local subtidal level (Figure 3).

27. Channel 5. The planting area was located on the southwest corner of Craig Key, where Channel 5 passes under the Channel 5 Bridge (Figure 2). During construction of the Keys bridges, vessels maneuvering barges to the site prop-washed carbonate sediments onto several hundred square meters of a turtlegrass meadow (Figure 4). Plantings were done about 2 years after the deposition.

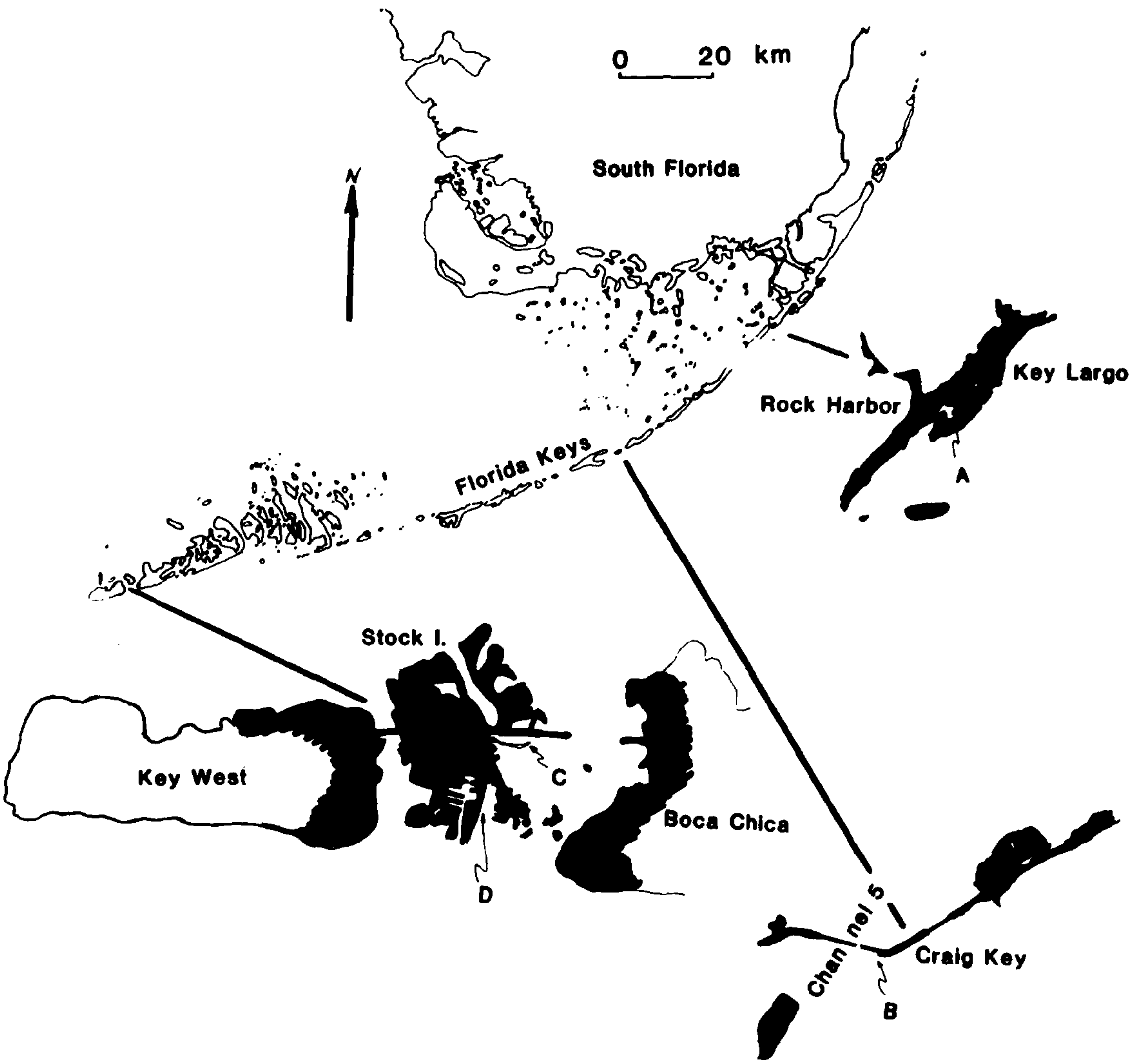

Figure 2. Map of south Florida including blowup sections of the Florida Keys where the four study sites were located (Site A = Rock Harbor, B = Channel 5, C = Boog Powell Marina, D = Stock Island)

Figure 3. Aerial photograph of Rock Harbor site. Arrow indicates study site adjacent to borrow pits. Emergent vegetation is red mangroves

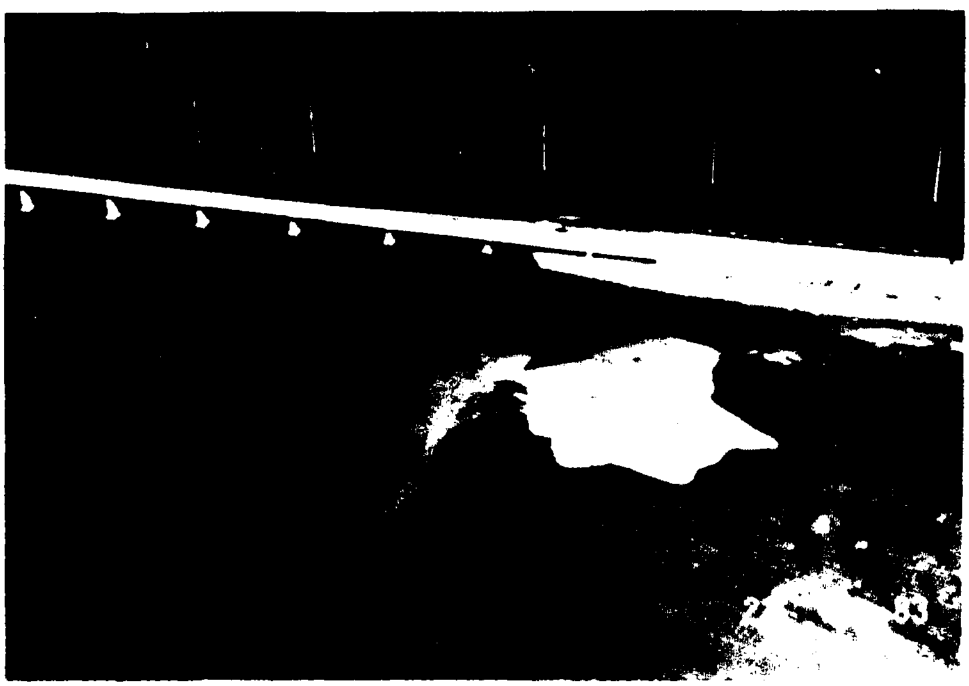

Figure 4. Aerial photograph of Channel 5 site. Arrow indicates middle of site. Channel 5 bridge (east end) is above arrow; Craig Key is to the right of the photograph

28. Boog Powell Marina. This site was located on the south side of the causeway entering Stock Island from the east (Figure 2). A fill access road was removed at this site 3 months prior to our planting (Figure 5).

29. Stock Island. This southernmost site was located approximately 1 km south of the Boog Powell site on a large flat directly across from King

Figure 5. Aerial photograph of Boog Powell Marina site. Arrow shows extent of planting area. Remaining road spit is seen in upper left. Natural turtlegrass meadow is seen to left of and below arrow

Point Marina (NOAA Navigation Chart, 1445, 12 February 1983; Figure 2). This area was a large turtlegrass flat that had been killed by thermal effluent from the power plant. Effluent had been diverted to a site offshore several years prior to our planting, leaving several acres of flat unvegetated except by macroalgae and sparse seagrass (Figure 6).

Figure 6. Aerial photograph of Stock Island site. Large arrow shows site amid macroalgae. Thin arrow shows part of the range of thermally induced denudation of seagrasses. Diversion canal is above arrows at the margin of the land

Bathymetry

30. Bathymetry of each site was surveyed relative to water height over the course of sampling visits. Values are given as average depths (Table 5).

Light

31. Light transmission data were collected using the same instrumentation and were sampled at approximately the same frequency as described for the northeast Gulf study sites (paragraph 15).

32. Among all the study locations, light quality and quantity were almost certainly not limiting, except at Stock Island. Values were never low enough to suggest light-limited mortalities by themselves (Table 5). Further reduction of light to limiting levels at the Stock Island site could have occurred from heavy macroalgal growth.

Temperature and salinity

33. These parameters were recorded during site visits using a glass thermometer and refractometer, respectively. Readings were taken at the middepth level in the water column. Temperature ranges were considerably narrower for these sites than for the Panama City sites. Rock Harbor had temperatures ranging from 16.2° - 32.0° C ($\bar{X}$ = 26.2° C). The salinity was a constant 30 o/oo. Channel 5 had a temperature range of 22.9° - 30° C ($\bar{X}$ = 25.6° C) with salinity constant at 32 o/oo. Boog Powell site was cooler than Stock Island, with a temperature range of 22° C to 32° C versus 31° to 38° C. The average for Boog Powell was 26.7° C; for Stock Island, 34.3° C. Temperatures at Stock Island were likely deleterious to seagrass growth. Salinities were comparable between these two sites at an almost constant 30 o/oo.

Hydrodynamic regime

34. Current velocities. Velocity was measured with propeller-type flowmeters as described in paragraph 18. Rock Harbor, Boog Powell and Stock Island all had very low current speed averages (5.6, <5, and <1 cm/sec, respectively). Channel 5 had considerably more flow, as might be expected given its close proximity to the channel. Velocities at Channel 5 ranged from 7.1 to 20.0 cm/sec with an average of 14.1 cm/sec.

35. Fetch. The maximum fetches of each site, taken together with flow conditions, group Rock Harbor, Boog Powell, and Stock Island all as low-energy sites. These three sites have maximum effective fetches of no more than 0.3 km. The Stock Island site is actually open to the south, but a 1-km-wide shallow flat lies between the study site and open water, dramatically reducing

wind-wave development. Hence, the authors use the term effective fetch herein to denote the approximately 0.3-km unbroken path that would allow wind-wave development. Channel 5, however, is a virtually open-water site with unlimited fetch from the south and a minimum depth of 1.5 m for incoming waves to negotiate at low water.

Sediment characteristics

36. Surface sediment samples were collected and organic matter analysis was done as described in paragraph 20. The carbonate sediments of these sites were analyzed by wet sieving. Large, identifiable fragments of seagrass were removed, and the sample was dried to a constant weight at 80° to 90° C. Samples weighing about 50 g dry weight were then homogenized with 50 ml of saturated sodium hexametaphosphate or sodium lauryl sulfate solution (40 g/liter) for 1 min. The sample was rinsed into a Geoscience wet sieve with 2.0- and 0.065-mm sieves. The sample was shaken on a "standard" setting for 10 min with a flushing rate of ≥ 1 liter/min. The sample remaining on each sieve was dried at 80° to 90° C to a constant weight and compared gravimetrically to the original for percent silt-clay (<0.065 mm), percent sand (>0.065 and <2.0 mm), and percent gravel (>2.0 mm, Wentworth scale). Percent silt-clay (remainder = percent sand or larger) and percent organic matter values are presented in Table 6.

Sediment flux rate and sediment depth

37. Sediment fluctuation rate was sampled as described earlier in relation to boundary stakes of known heights (paragraph 22). No significant sediment height fluctuation occurred at Rock Harbor, Boog Powell, or Stock Island. Channel 5 experienced a sediment height drop of -9.6 cm between 19 February 1983 and 2 April 1983 due to an isolated winter storm event. Sediment height fluctuation at Channel 5 was marginal throughout the remainder of the study period.

38. Sediment depth to consolidated substrata (penetration depth with a 1/2-in. steel rod driven by a 3-lb (1.4-kg) sledge hammer) was quite variable between sites. The road spit removal sites, Rock Harbor and Boog Powell, had average sediment depths of 18.6 and 14.9 cm, respectively. Channel 5 and Stock Island had unlimited sediment depth (>1.5 m). The relatively shallow sediment depths at Rock Harbor and Boog Powell had not impaired seagrass

growth as of June 1985. The eventual development of turtlegrass may be slower here as suggested for shallow sediment areas by Scoffin (1970) and Zieman (1972).

Effects of biota on transplants

39. Pinfish were observed grazing upon transplants in the south Florida sites. Grazing was most notable at the Boog Powell site but largely on manatee grass. Shoot lengths were reduced by at least one-half.

40. At Stock Island, flora, not fauna, were apparently prime contributors to the demise of the plantings. Dense assemblages of the algae *Laurencia* covered the plantings. The added shading and flow reduction effects of algae so decreased light and possibly elevated temperatures to the point that the seagrasses did not grow well. Seagrasses were also in direct contact and possibly in competition with *Halimeda*, *Udotea*, and *Caulerpa* spp. In extremely sheltered areas of south Florida such as this, spring plantings of seagrass might be better in order to reduce possible competition with macroalgae.

PART III: POPULATION GROWTH STUDIES

41. Populations of seagrass increase through sexual as well as asexual or vegetative reproduction. Asexual reproduction is of immediate interest to the transplanter, though sexual reproduction may provide additional recruitment to a transplant site which would enhance coverage rates. Seedling recruitment, however, is quite variable and should not be counted on over short time periods to replenish damaged areas with seagrass coverage. Nonetheless, seedling recruitment and vegetative encroachment from adjacent areas must be accounted for in population studies, especially in transplant situations such as this one which mimic the pioneering stage of succession.

42. Seedling recruitment was minimal in the study areas, simplifying data presentation. The lack of seedling recruitment was likely due to the fact that some of the study sites were recent or active disturbance sites with little or no sediment seed bank reserve. Also, seasonal seedling recruitment might not yet have occurred. Many studies have been done on seed production (Churchill and Riner 1978; Harrison 1979; Durako and Moffler 1981; McMillan 1981; Phillips, Grant, and McRoy 1983; Silberhorn, Orth, and Moore 1983; Williams and Adey 1983), but few demographic surveys have been made concerning seed germination and subsequent survival and growth -- requisite data for a complete population study. Where studies have been done, seedling dispersal and germination vary widely (Grey and Moffler 1978, Lewis and Phillips 1980, Williams and Adey 1983, Fonseca et al. 1985b).

43. Transplant population growth was assessed using treatments arranged in grids (Tables 1 and 4). Controls of the same dimensions were placed among the grids but were unplanted. Assessment of recruitment into the unplanted grids was performed by special surveys or during regular site visits. Recruitment of species different from those planted in a grid was recorded during surveys of the transplanted populations. We determined that no significant change in planting unit (PU) shoot numbers would be discernible in our surveys due to natural recruitment. Transplants were established using the methods described in Fonseca et al. (1985a) and in Part IV.

44. Population growth rate and areal coverage were assessed in a consistent manner for all sites. At time 0 (planting day), PU's were arbitrarily selected and counted for numbers of shoots and, where appropriate, numbers of apical meristems. Those same PU's were also measured for bottom area covered

by averaging the width (d, in metres) of the planting on two perpendicular axes and computing area as

$$\pi\ (^{d}/2)^2 = \text{area} \tag{2}$$

The number of PU's surviving was counted until establishment was apparent (within 90 days). At each successive survey, 10 randomly selected PU's were counted per treatment for number of shoots and areal coverage. When the units grew so large that they began to merge with neighboring planting units, a different survey method was used. A 1-sq m quadrat was divided into a grid of 16 0.25- by 0.25-m subsections (Figure 7). The quadrat was placed over a randomly selected PU and centered on the original planting spot. When the grid (Figure 7) was placed over the origin of a PU, five subsections were randomly selected and counted for numbers of shoots. The average number of shoots from those five counts was extrapolated to estimate the average number of shoots per grid for that location. These values were then averaged for a grand mean of shoots per unit area. The following formula provided an estimate of the areal cover of the PU:

$$\text{No. subsections with seagrass/total no. subsections sampled} \\ = \text{Percent area covered with seagrass/sq m of bottom} \tag{3}$$

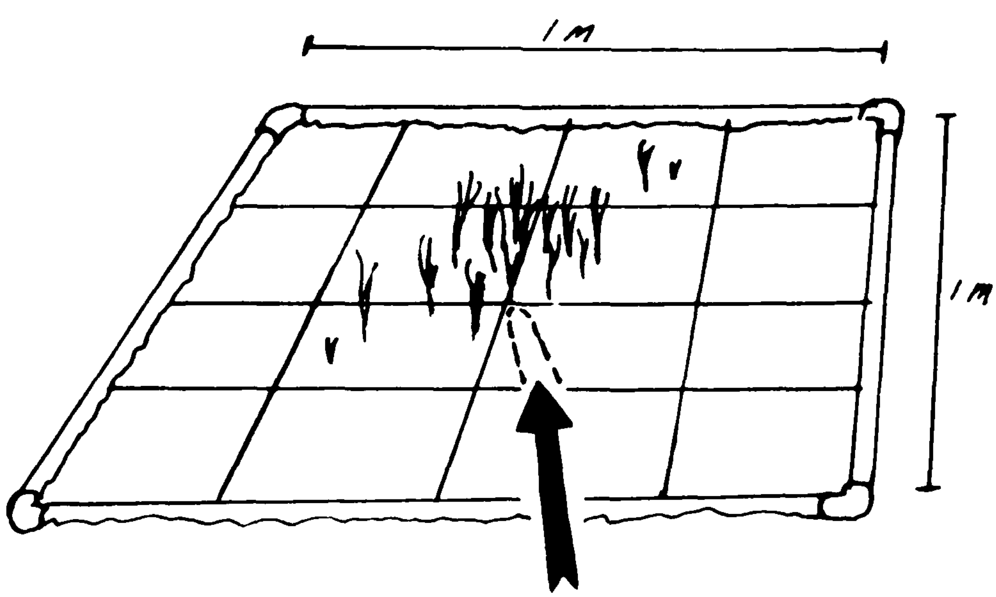

Figure 7. Quadrat used for shoot counts and areal coverage after coalescence of PU's. Arrow points to buried anchor from original planting unit

45. Data were compiled in two categories: before PU's coalesced and after PU's coalesced. This was done for two reasons: (a) the phase of growth up to the point of coalescence is what is of immediate concern to the transplanter, and (b) survey methods changed at this point. Therefore, where sites coalesced, only the precoalescence data were used to generate the planting arrangement tables.

46. In this report, all data are grouped by geographic area (Panama City versus Florida Keys). The goal was to replicate treatments across as many environmental conditions as possible within a geographic area. By grouping these independently assessed plantings, representative population growth and areal coverage models for the geographic area in question are provided.

Northeast Gulf Study Sites (Panama City, Florida)

Survival of transplants

47. Planting unit survival was poor considering the relatively quiescent hydrodynamic regimes of these sites. The high level of fish grazing on transplants and some excavation for shellfish by animals (possibly rays or blue crabs) were considered responsible for much of this loss. After 43 days, 35 percent of the manatee grass and 13 percent of the shoalgrass plantings were gone at the Redfish Point site (Figure 1, Site A). At the same time, 13 percent of the manatee grass and 15 percent of the shoalgrass were lost from the Treasure Island site, again, largely due to grazing (Figure 1, Site B). Fourteen months after transplanting (June 1985) all manatee grass was gone from both sites and only 30 percent of the shoalgrass PU's remained at Treasure Island. Evidence of bioturbation (excavations and broken bivalve shells) as well as grazing on the remaining shoalgrass were suspected as the reasons for the demise. By June 1985, the remaining shoalgrass plantings had begun to coalesce.

48. Turtlegrass transplants (planting date 31 May 1984) at both locations experienced some losses, though very little grazing was evident. Ten percent were lost from Redfish versus 30 percent from Treasure Island in the first year. The higher loss from Treasure Island was possibly due to planting the turtlegrass shoots too shallow in the sediment. They may have been eroded by the boat wakes from traffic entering the nearby marina.

Flowering and seedling recruitment

49. No flowering of transplanted stock was observed. Random 1-sq m quadrats (10 per treatment at each site) revealed no seedling recruitment by the end of the study period. Occasional small clumps of vegetative stock drifted onsite, but there was no evidence of permanent establishment.

Shoot generation rates

50. Shoot generation rate data are presented in Figures 8a and b and Table 7 for shoalgrass and manatee grass. Manatee grass had a rate lower than shoalgrass in these northeast Gulf sites. Planting units at time 0 (Redfish) had an average 17.2 shoots for shoalgrass (3.4 of which were terminals) and an average of 5.1 shoots for manatee grass; Treasure Island site values for the same parameters were 21.4, (3.8), and 5.2 shoots PU^{-1}, respectively. Computing the number of shoots PU^{-1} at 365 days using these regression models, one would expect shoalgrass to have >1,000 shoots while manatee grass would have only 160 shoots. (Turtlegrass plantings are described with the south Florida data set.)

Areal coverage rates

51. As with shoot generation rates, the areal coverage rate for shoalgrass was slightly greater than that of manatee grass (Figure 9). These rates are not unlike those of shoalgrass plantings done in Beaufort, N. C. (Fonseca et al. 1985b). There is only one regresson line for each of these species in the Panama City area (in contrast to the Florida Keys sites as will be seen) because there was no distinct "best case" or higher coverage rate treatment; all treatments within a species spread at similar rates.

South Florida Study Sites (Florida Keys)

Survival of transplants

52. As described earlier, most of the south Florida sites were in low-energy areas. As a consequence, survival of PU's past the second monitoring period was quite good (Table 8). Rock Harbor and Boog Powell had a consistent 100-percent survival, while Channel 5 lost many PU's from the February planting because of a severe winter storm. The relative calm following the summer planting resulted in generally higher survival (Table 8). Stock Island had good survival initially but eventually died out. This was due apparently to high temperature, competition and shading by macroalgae and, possibly, herbivory.

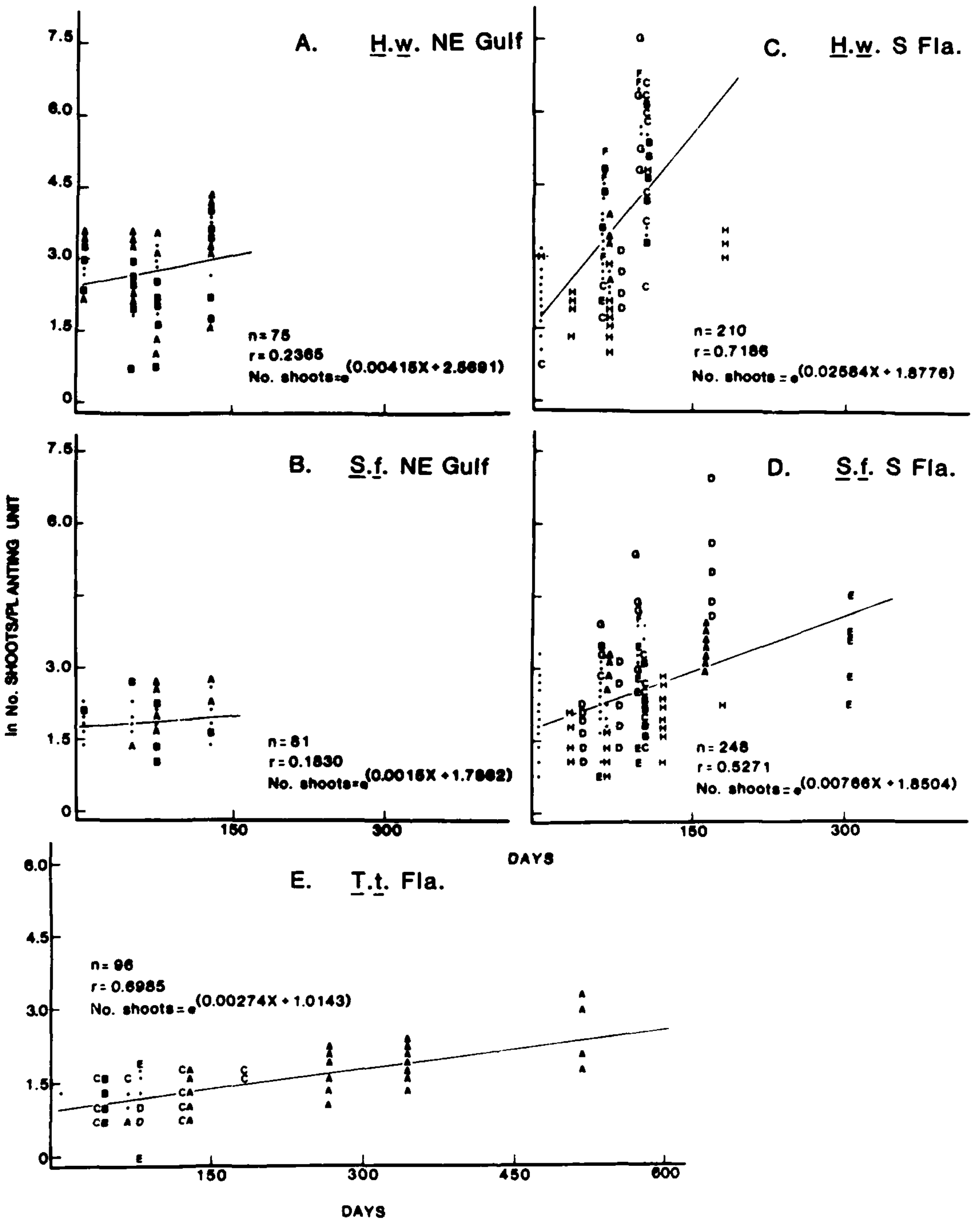

Figure 8. Regression of the ln of shoots per PU over time for shoalgrass (H.w.) and manatee grass (S.f.) in the south Florida and northeast Gulf sites and northeast Gulf sites and for turtlegrass (T.t.) for combined south Florida and northeast Gulf sites prior to coalescence of PU's. Letters refer to individual PU's in different locations (Tables 1 and 4)

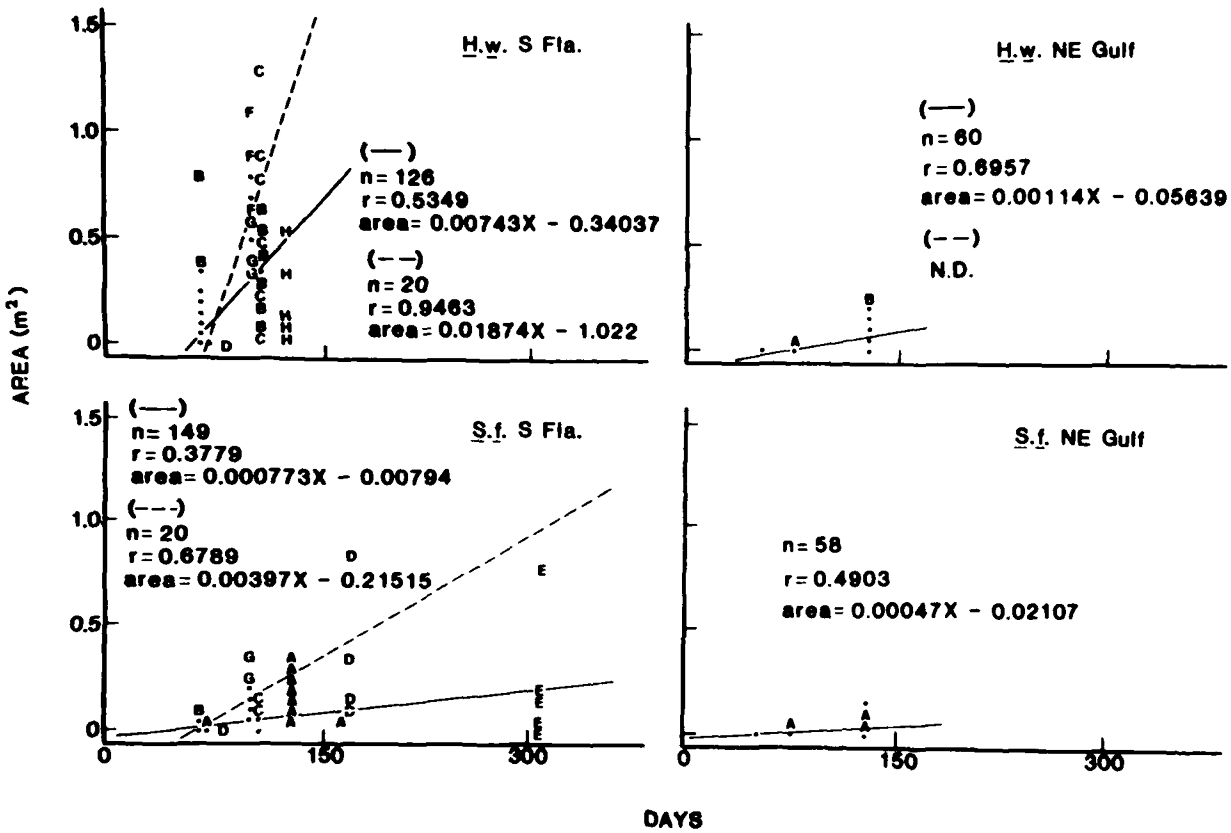

Figure 9. Regression of the area (sq m) of PU's over time for shoalgrass (*H.w.*) and manatee grass (*S.f.*) in the northeast Gulf and south Florida sites prior to coalescence. Letters refer to individual PU's in different locations (Tables 1 and 4). Solid line represents all data; dashed line represents fastest covering planting locations

53. The Channel 5 site was inadvertently overplanted with shoalgrass by a contractor working for the State of Florida in September 1983. This precluded further quantitative monitoring of this site for shoalgrass. By November 1983, considerable loss of the contractor's plantings was observed. The contractor used the same technique described in this report, except the runners were not attached to the anchors. Although the precise shoot growth and areal coverage rates could not be determined (data after the overplantings are excluded from growth models of shoalgrass), enough combined plantings eventually survived to provide almost 50-percent cover of the shoal area by summer 1984.

Flowering and seedling recruitment

54. No flowering of any transplanted stock was observed as of June 1985. Some development of stoloniferous growth (sensu Cambridge, Carstairs, and Kuo 1983) or "aerial runners" was noted on shoalgrass at Rock Harbor.

55. Only turtlegrass seedlings were observed to recruit into the transplant sites. Seedlings were observed as early as November 1983 at all locations except Stock Island, where none were observed. Using randomized surveys concomitant with shoot counts, seedlings were encountered in the quadrats only at Boog Powell. There, seedling density was 0.17 seedling m^{-2} or one seedling per 5.8 m^2 ($n = 35$, 1-sq m samples). Growth of natural seedlings was monitored and was equivalent to shoot addition rates recorded for this study's seedling transplants, those of Derrenbacker and Lewis (1982), and whole shoot transplants of turtlegrass done at Boog Powell insofar as only 3 to 5 shoots were observed on natural seedlings by July 1984. As a result of these surveys, no corrections were found to be necessary for the population growth and coverage models.

Shoot generation rates

56., These rates are divided by species but include all surviving study sites in south Florida. Shoot generation rates were so much faster in south Florida than in other areas that population growth was further divided into coalesced and uncoalesced categories (see paragraph 45). Shoalgrass had an average time 0 count of 22.1 shoots PU^{-1} for all natural frequency plantings (2.9 of which were terminals) and 7.1 shoots PU^{-1} for terminal plantings with an overall average of 13.9 shoots PU^{-1}. Manatee grass had an average time 0 count of 4.4 shoots PU^{-1} for all natural frequency plantings (0.7 of which were terminals) and 5.0 shoots PU^{-1} for terminal plantings with an overall average of 4.9 shoots PU^{-1}. Turtlegrass had an average time 0 count of 2.8 shoots PU^{-1} (all Florida plantings). Each turtlegrass planting unit consisted of a rhizome with a single apical meristem; the shoots counted above were still attached to the rhizome, as they are naturally.

57. The data for these sites are given in Figures 8c,d,e, 10 and Table 9. The uncoalesced rates for shoalgrass (Figure 8) are generally an order of magnitude greater than at Panama City (Figure 8). The coalesced shoot generation rate (Figure 10) is intermediary between Panama City sites (Figure 8) and uncoalesced Florida Keys (Figure 8). Actually, an asymptote is apparently reached shortly after coalescence in Figure 10, and the relation could perhaps be better described by a quadratic equation. For comparative purposes, we have continued use of linear regressions. Once a transplant has coalesced, one of the major project goals has been achieved. Also, the population growth rate data prior to coalescense must be considered separately if one wishes to compare these data with the areal coverage model. Only uncoalesced data are used for areal coverage models.

58. Stock selection apparently made little difference in the resultant growth rates. The slopes of regression lines for treatments using unculled stock (natural frequency of terminal meristems) of shoalgrass increased at almost the same rate as for the treatments planted with PU's composed of only terminal shoots (Table 9). As with shoalgrass, the use of natural frequency plantings versus terminal plantings made little difference in the shoot generation rate of manatee grass (Table 9). If anything, natural frequency plantings for both species produced shoots at a slightly faster rate than terminals alone, although this difference is marginal.

59. Even in south Florida, planting season appears to have a significant impact on shoot generation rate for shoalgrass and manatee grass. Although plantings were successfully performed in both February and June for all three species, the slopes of the lines for February versus June plantings were considerably lower for shoalgrass (February 1983 range of slopes = 0.002 - 0.008; June 1983 range of slopes = 0.027 - 0.047) but less so for manatee grass (February 1983 range of slopes = 0.004 - 0.017; June 1983 range of slopes = 0.005 - 0.021) (Table 9). Since seasonal effects on growth are

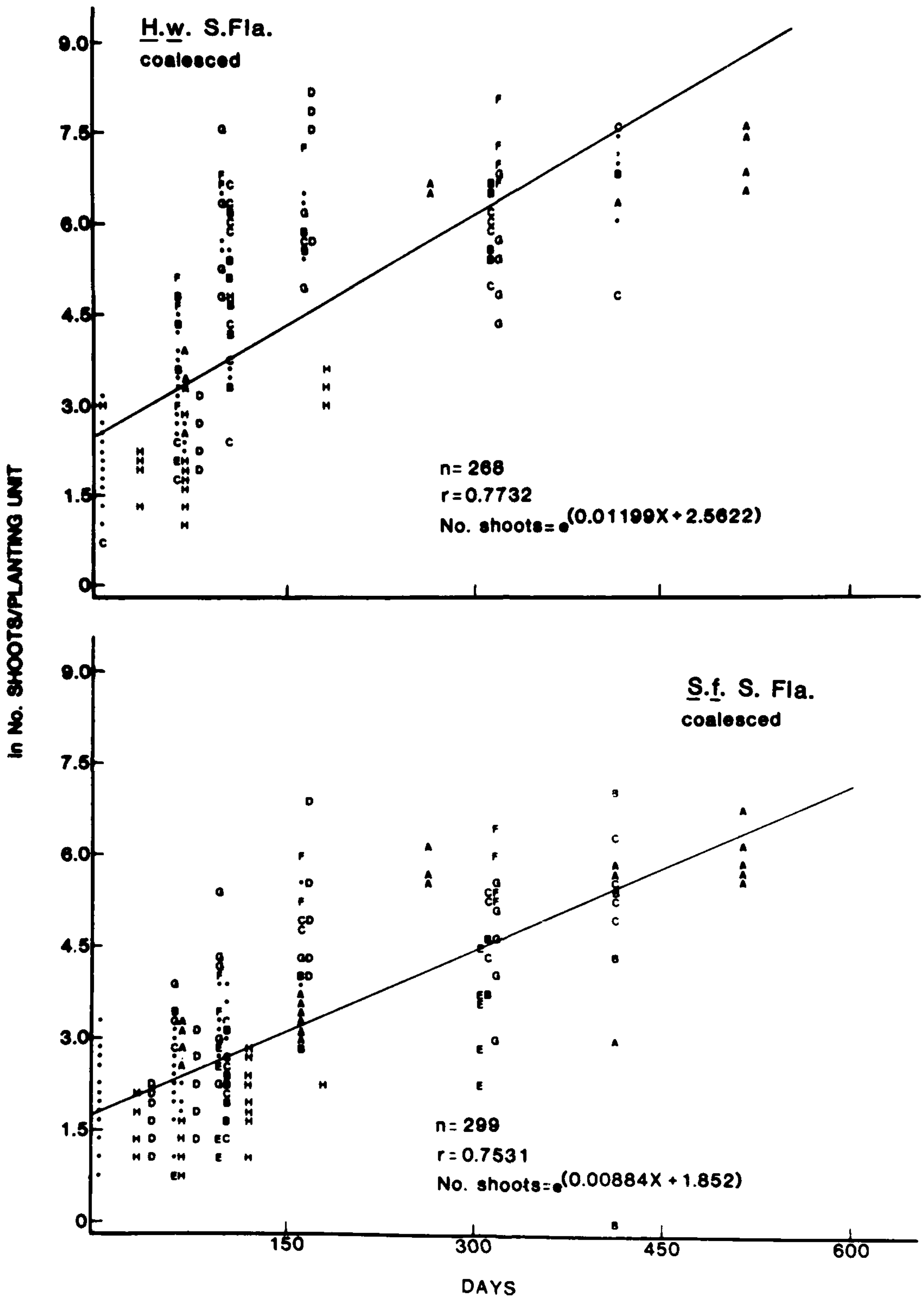

Figure 10. Regression of the ln of shoots per PU over time for shoalgrass (H.w.) and manatee grass (S.f.) in the south Florida sites including time after coalescence of PU's. Letters refer to individual PU's in different locations (Table 4)

noticeable even at these latitudes, more northerly sites, which have colder winters, should be considered suitable only for spring plantings for these species.

60. There was little difference in the regression lines for coalesced and uncoalesced manatee grass. When all data were used (Figure 10; coalesced), the manatee grass regression line had a better correlation coefficient and actually had a steeper slope, suggesting a continued population growth even after coalescence as compared with the rapid asymptote in shoot numbers displayed by shoalgrass (Figure 10).

61. The lower population growth rate of shoalgrass in the northeast Gulf as compared to south Florida is likely due to the differing climatic conditions of the two areas. Several factors -- proximity to warm water, latitude, and influence of continental air masses -- produce populations in the northeast Gulf that have dramatic summer growth and negligible winter growth, and sometimes complete foliar dieback to the rhizomes (pers. observ.). The seasonal response and data from Carangelo, Oppenheimer, and Picarrazi (1979, p 258) suggest that Gulf of Mexico plantings of shoalgrass and probably other marine angiosperms must be initiated in the spring and cannot be planted anytime during the year, as stated by Phillips (1980, p 20). The response of the shoalgrass plantings was very similar to that reported for the same species in North Carolina (Fonseca et al. 1985b) and Texas (pers. observ.). Spring plantings should be done north of Tampa and west to the Rio Grande (at least). Plantings south of this latitudinal range can be executed any time of the year, but our data suggest that even south Florida plantings do better starting in the early spring.

62. The combined shoot generation rates for turtlegrass are given in Figure 8e and for individual sites in Table 9. All data for Florida, from both study sites, were combined. The regression model (Figure 8) predicts that even after 600 days, the average number of shoots per PU would be 14. This is corroborated by other studies (paragraph 55) and the authors' observations of natural seedling growth. Because of the lack of shoot production, no areal coverage models were developed for this species. Turtlegrass is clearly not the primary species to use in transplanting operations. This slow growth means that destruction of turtlegrass systems could take decades to mitigate.

Areal coverage rate

63. Areal coverage rates were compiled for uncoalesced shoalgrass and manatee grass data only (Figure 9). This was done because after the PU's began to coalesce and reached 100-percent coverage in some areas, the areal spreading of rhizomes from a given PU could not be further documented. Thus, overlap was a problem for areal coverage estimates, but was less so for shoot generation where the changes in shoot density would have been indicative of an unabated increase in the rate of new shoot production. That rate apparently decreased for shoot generation, suggesting that areal spread of rhizomes at coalesced sites may also have slowed. Another explanation is that shoot mortality may have increased, stabilizing the population level (measured as density). The overall regression line and one for selected best-case situations are shown in Figure 9. These lines are utilized in planting arrangement calculations discussed in later sections. Not all sites in south Florida coalesced during the monitoring period. Channel 5 and Stock Island plantings did not coalesce, although plantings at Rock Harbor and Boog Powell did. As with the shoot generation rates, the areal coverage rates for shoalgrass and manatee grass at the northeast Gulf sites were less than those for south Florida sites (Figure 9). These rates suggest that disturbance of natural meadows of these seagrass species will take substantially longer to recover naturally than areas farther south, such as the Florida Keys.

PART IV: TRANSPLANTING TECHNIQUE

Harvesting and Storing Transplant Material

Identifying preferred harvest sites

64. Previous publications by Fonseca et al. (1985 a,b) contain the directions for planting shoalgrass and manatee grass. This Part (IV) deals primarily with turtlegrass, which has not had prior discussion. Information on transplanting shoalgrass and manatee grass is provided here where a significant advance in our data base has been accomplished.

65. The preferred method for transplanting turtlegrass should utilize seeds or seedlings obtained from drift or wrack lines. This can be the least destructive of the three viable techniques. Seedlings that have already settled and established should be moved from existing beds only as a last measure. Likewise, sprigging and plugging should be performed only if seedlings are unavailable because sprig and plug harvest techniques may have long-term impacts on the donor beds.

66. Salvaging turtlegrass for transplanting from areas slated for destruction is recommended (Phillips and Lewis 1983). Otherwise, only low-energy sites are suggested for shoot harvest so as to prevent development of migrating scour areas (Patriquin 1975). Several surveys were conducted in south Florida to determine the availability of turtlegrass sprigs (rhizome apical meristems and associated shoots). We found that densities of +150 apicals m^{-2} were common, indicating that natural meadow harvest could be conducted on a small scale to provide some transplanting material (Table 10).

Harvest technique

67. Harvest of seeds or seedlings of turtlegrass is most easily accomplished from wrack lines. Sprigging of turtlegrass sometimes requires excavating an area of bottom and sorting out the rhizome apical meristems with attached short shoots, rhizome, and roots. Plugs are obtained with a coring device constructed of a hard plastic or rigid metallic material. Sod or plug collection of sprigs from turtlegrass meadows should be followed by planting of faster growing shoalgrass and/or manatee grass into the excavated areas.

68. The core tube must have a handle, and the base should be sharpened so that when it is inserted into the sediment and twisted, it severs the dense rhizome mat. Usually the core must be inserted to a depth of at least 20 cm-

25 cm. The device must have a removable stopper at the top which is sealed so that when the core is removed from the sediment, a vacuum is created inside the device and an intact plug of sediment and seagrass is extracted within the core tube. The plug can either be retained with the core tube or released into an intermediate holding device. Post-hole diggers have also been used for plug collection. The sediment plant matrix usually has little physical integrity and extruding the plug can be a difficult job. A sophisticated coring device can be constructed with a removable sleeve so that, when the plug is extracted from the core tube, it remains intact inside the sleeve. This type of device is most appropriate in situations where one intends to store the plugs for a period of time. The core holes in parent beds makes the replanting of faster growing species (paragraph 67), as a repair procedure, difficult if not impossible.

Storage guidelines

69. The sediment-free mats or runners of seagrass should be stored in either flowing or aerated seawater with environmental conditions as near ambient as possible. Substantial differences in the temperature or salinity of the storage water could promote physiological shock in the plants which, in addition to the stress induced by transplanting, reduces the probability of a successful planting. The sophistication of the storage apparatus should be a function of the anticipated holding time and the availability of resources. Without circulation equipment, it is recommended that planting material be stored in situ for no longer than 36 hr. Where the collection and planting are concurrent and there is little delay, the storage apparatus can consist of simple plastic trash cans. For overnight outdoor storage, planting material can be retained in coarse mesh nylon bags hung overboard from a pier or boat. For prolonged storage, floating pens with shaded tops that allow appropriate light penetration are suggested.

Preparing Planting Units

70. A planting unit of shoalgrass, manatee grass or turtlegrass consists of a section of rhizome that has at least two to five shoots and the apical meristem. Properly harvested aerial runners will require no sorting prior to transplanting. If the plant material was harvested by digging, PU's consisting of at least three healthy rhizomes bearing a minimum of two and preferably five intact shoots per rhizome will need to be sorted from the mat.

71. Anchors must be used to secure the plant or planting material to or in the sediment. Anchors can be made from pieces of sturdy wire approximately 8 in. (20 cm) in length and bent into U-shaped pins. Bent sections of coat hangers or commercially available erosion control fabric pins work well.

72. Additional preparation may be necessary, depending upon the current velocity at the transplant site. In moderate- to high-current areas, PU's are attached to anchors by twist ties (Fonseca et al. 1985a). The anchor should be attached to a sturdy portion of the runner(s) or rhizome(s). In low-current areas it is not necessary to attach PU's to anchors; the appropriate number of anchors and transplant stock need only be brought to the transplant site. A bare-root turtlegrass seedling PU consists of one to three short shoots with attached roots and rhizome and a rhizome apical meristem. The number of shoots will depend on the age of the seedlings. Care should be taken not to damage the rhizome or short shoots when attaching the anchors to the plant. If available, a flowing seawater table is ideal for sorting and preparing all PU's. An individual PU should be prepared as rapidly as possible to avoid desiccation of the living plant material. When used as a PU, a plug of turf is retained intact and would not require any additional preparation prior to planting.

Planting Method

73. Proper handling and spacing of PU's is essential for a successful transplant. Planting units should be kept covered with seawater at all times and handled carefully to reduce breakage and transplant stock.

74. Transplanting can be done by wading in shallow-water areas (up to about 0.6 m deep) or by scuba divers in deeper areas. Under certain circumstances, some preliminary site preparation is necessary. For example, in moderate- or high-current areas, in deep water, and in low-visibility conditions, planting grids with the proper spacing should be established using a weighted line marked in the calculated spacing units or by other measuring devices. Depending on the specific requirements of the transplant, grids can be established with the weighted lines for the quantitative evaluation of transplant compliance and success parameters. Planting methods should always be closely coordinated with compliance and success monitoring requirements to ensure that the necessary evaluations can be made.

75. Planting units of shoalgrass and manatee grass need to be secured to the sediment surface but not buried. The U-shaped anchors are placed over

the rhizome or runner of the PU and then pushed into the sediments until the PU is held firmly against the bottom and will not be removed by current or wave action. Turtlegrass seedlings or seeds may be attached to anchors and similarly planted. In contrast, turtlegrass sprigs must be buried so their rhizomes are at a depth equal to that from where they were harvested. As a consequence, there should be a sufficient depth (at least 10 and preferably 20-25 cm) of unconsolidated sediment at the planting site for this species to thrive (Zieman 1972). Greatest efficiency is obtained when personnel work in teams, with one worker holding the planting unit in position while the other worker places the anchor to secure it. When planting units are already attached to anchors, one worker plants while another individual provides a continuous supply of PU's. Plugs of any seagrass are especially cumbersome and may be difficult to work with in high-current areas and in deep water. Each individual plugging site must be prepared by coring and extracting a volume of sediment equivalent to or greater than the PU. The plug is then extruded into the hole and anchored by its own weight. In coarse rubble sediment this may be impossible, and in unconsolidated sediments the walls of the hole will collapse. These limitations must be carefully examined before determining if plugging is appropriate at a site.

Plant Material Requirements: shoalgrass and manatee grass

76. Fonseca et al. (1985a) report on transplanting techniques for these 2 species. In this report, we have elaborated on those data and distinguish between north and south Florida, and so present the following discussion which differs slightly from the previous report.

77. To determine the required number of PU's and the spacing between them for a transplant area, first determine where the species will be planted, the desired number of days for transplant stock to cover the area, and the size of the area in square metres.

78. Based on the desired number of days to coverage, determine the Y value (square metres of area covered per PU) from Table 11. The Y values are listed for each of the major geographical locations where shoalgrass and manatee grass occur in the northeast Gulf of Mexico and in south Florida.

79. To calculate the number of PU's needed for a transplant site, use the following formula:

$$\text{Number of PU's} = \frac{\text{Area of transplant in square metres}}{Y} \qquad (4)$$

To calculate the spacing between PU's in the planting grid, use the following formula:

$$\text{Distance between PU's in metres} = \sqrt{\frac{\text{Area of transplant in square metres}}{\text{Number of PU's}}} \qquad (5)$$

80. As an example, assume a transplant area of 1 acre (0.4 ha) in south Florida is to be planted with manatee grass. The transplants are expected to cover the area in 125 days. There are 4,046 sq m in 1 acre and the Y value for 125 days (Table 11) is 0.0886. Thus,

Number of PU's

$$\frac{4{,}046}{0.0886} = 45{,}665 \text{ PU's}$$

Distance between PU's

$$\sqrt{\frac{4{,}046}{45{,}665}} = 0.2976 \text{ m}$$

Projecting 1 acre of coverage in approximately 125 days would require planting 45,665 PU's spaced 0.2976 m apart. The Y values were obtained from the formula:

$$Y = m\,x + b \qquad (6)$$

where

Y = area covered per PU in square metres

x = number of days

m = slope for regression of area covered on time

Data used to develop the equations for estimating the areal coverage of PU's were obtained from experimental transplants (Figure 9).

81. Persons designing seagrass transplants may desire a longer time to obtain complete cover than is presented in Table 11. New Y values for time in

days greater than 200 may be obtained by regressing the Y values in Table 11 for a given species/geographic location on the corresponding time in days. The resulting equation can then be solved for Y given the desired number of days. In doing so, the model would predict that far fewer PU's would be needed if, for example, 500 days were chosen as an acceptable time to complete cover. This reduction in planting units would indicate significant cost savings. There are, however, serious problems with such extrapolations.

82. If we consider the asymptotic tendency of population growth in Figure 10, we cannot be sure that the exponential growth prior to coalescence is actually continuing. The asymptotic behavior of Figure 10 may simply be a density-dependent population growth slowdown or the result of senesence of shoots at the end of their life cycle in the presence of exponential growth. The point is that since we do not have uncoalesced growth rates for over 200 days for these species in most locations, we can only speculate that their growth will continue as predicted. There is a greater possibility of unabated population growth in the south Florida area since we demonstrated successful February and June plantings in the Florida Keys. There is a near cessation of growth in the northeast Gulf in the winter. A linear extrapolation of these data would not necessarily be applicable in this case.

83. Other, more subtle problems can develop when planting PU's at greater spacing in an attempt to reduce costs. Widely spaced plantings are likely to suffer more from grazing than recommended spacings. Widely spaced plantings have also much less potential for stabilizing the bottom, making them susceptible to erosion. We suggest that transplanting operations adhere closely to our recommended PU spacings. If extrapolation to reduce cost must be done, we suggest that these numbers not be used past 2 years.

Plant Material Requirements: turtlegrass

84. Whereas the expected coverage rate for shoalgrass and manatee grass can be modeled in tens or hundreds of days, turtlegrass coverage occurs on the order of years. The formation of shoots and especially of new rhizome apical meristem is very slow for this species. Therefore, lateral branching is not a very rapid means of areal coverage. Coverage by turtlegrass PU's begins in a linear rather than radial fashion and requires more planting material to achieve a desired cover. For these reasons and because most investigators have failed to report the necessary data, we were unable to develop a reliable

predictive model of the expected areal coverage rates and must rely on using a shoot growth model as a basis for determining plant material requirements.

85. If a transplanting effort is intended to establish a turtlegrass meadow, we should expect to achieve a density of shoots similar to a mature, undisturbed seagrass meadow or to the meadow that is to be impacted. Seagrass densities vary tremendously between habitats, so any value is a compromise of habitat heterogeneity. Our predictive model for turtlegrass shoot population growth is shown below with a computation indicating the predicted yield of shoots over time from a single planting unit. This model was developed from a transplant of sprigs but should also be applicable to the growth rate of seedlings. The growth rates of natural seedlings (W.J. Kenworthy and M.S. Fonseca, pers. observ.) and of transplanted seedlings (Derrenbacker and Lewis, unpublished data) are similar to sprigs using the equation:

$$Y = mx + b \tag{7}$$

where

Y = number of shoots (yield)

x = number of days

m = 0.01818

b = 1.1107

such that

Days	No. shoots/seedling (Derrenbacker and Lewis, unpubl. data)	No. shoots/PU (Regression equation Figure 8)
365	8	7.5
730	14	20.4
1,095	22	55.4

A representative shoot density for a mature turtlegrass meadow is on the order of 1,000 to 1,500 shoots m^{-2} (Zieman 1982). We should then expect a transplanted meadow to achieve a similar density.

86. As an example for estimating plant material requirements, assume that the area to be planted is 100 sq m (10 by 10 m) with an expected final density of 1,000 shoots m^{-2} (based on personal observations of undisturbed natural meadows). The total number of shoots per 10 sq m is then 100,000 shoots. Further, assume that we expected to reach this cover in 3 years. Using

our model, we would expect an average yield of 55 shoots PU^{-1} over a 3-year period.

$$\text{Number of PU's} = \frac{100,000}{22} = 1,818$$

Thus, we would need a minimum of 1818 PU's. Spread over a 100-sq m area, these 1,818 PU's (either as seeds or sprigs) would be spaced roughly on 0.25-m centers. It may be even more necessary to extrapolate the turtlegrass model further than 3 years in order to reduce planting costs. However, the data base is limited to observations during a period of 3 years and the reliability of any such extrapolation cannot be determined (see parallel discussion for shoalgrass and manatee grass, paragraphs 81-83). As an illustration of these limitations, consider a transplant of a much larger but not unrealistic scale. To cover 1 acre solely with turtlegrass in 3 years at a density of 1,000 shoots m^{-2} would require 73,580 PU's. To cover that same area in south Florida with shoalgrass would require 2,479 PU's planted on 1.3-m centers and would take only 200 days.

87. It is quite clear from this exercise that a turtlegrass transplant could be a highly expensive undertaking. To be feasible, the allowed coverage time should be extended, but more data are needed to support the extrapolated growth rate beyond 3 years. Also, an extended time for coverage means that the resource is not functioning naturally or at its full potential for an extended period of time, and this increases the environmental cost of the impact.

Labor Requirements

Harvesting and preparation of planting units

88. Based on the results of a series of timed trials using workers familiar with seagrasses, but not with transplanting (authors were excluded), it was determined that aerial runners of shoalgrass and manatee grass can be harvested at a rate of approximately 500 work-hour^{-1}. Plant stock can be harvested by shovel at 18,000 shoots (or the equivalent of 3,000 PU's) work-hour^{-1}. Actual harvest rates will vary according to the density of shoots at a donor site. If PU's are to be attached to the anchors, the labor rate in preparation is 100 PU's work-hour^{-1}. Based on the results of time collection trials, it was estimated that turtlegrass sprigs with rhizome apical meristems

can be collected from motorboat cuts on the order of 50 work-hour^{-1}. There are no reliable estimates for harvest rates of seeds or seedlings, although the time requirements are thought to be highly variable. For example, collections of individual seeds and seedlings using scuba should be quite time-consuming. However, if a site such as reported by Lewis and Phillips (1980) is located where there may be thousands of seeds and seedlings stranded on an easily accessed wrack line, collection time could be minimal. Additionally, the establishment of viable indoor and/or outdoor nurseries could, with more research, abbreviate the time and cost of providing planting stock. The labor rate for preparation of sprigs or seedlings that are attached to anchors is also 100 PU's work-hour^{-1}. In very quiescent areas anchors need not be attached, eliminating this labor expense. No additional preparatory steps are needed for plugs (paragraphs 67-68).

Planting

89. In water depths up to 0.6 m, planting can be conducted by wading. In deeper water, scuba divers are often required. For most conditions, the planting rate for wading non-scuba assisted workers is about 150 PU's work-hour^{-1}. The planting rate for scuba-assisted workers is about 175 PU's work-hour^{-1}. Although scuba-assisted workers are at least 15 percent faster than non-scuba assisted workers, wage differences have always resulted in non-scuba workers being more economical when conditions permit.

90. To continue the example of planting 1 acre of shoalgrass, the work-hour requirements for collection, fabrication, and planting are computed below.

Collection of aerial runners

$$43{,}522 \div 500/\text{work hour} = 87 \text{ work-hour(s)}$$

Collection of dug plant stock

$$43{,}552 \div 3{,}000/\text{work hour} = 14 \text{ work-hour(s)}$$

Fabrication (only if PU's are attached to anchors)

$$43{,}552 \div 100/\text{work hour} = 435 \text{ work-hour(s)}$$

Planting

$43,552 \div 150$/work hour = 290 work hour(s)

Total work-hour requirements are subject to two variables -- whether dug plant stock or aerial runners are to be used, and whether or not the anchors are to be attached to the PU's. Fabrication accounts for 435 work-hours; thus, planting in high-energy environments will be the most costly (813 work-hours if aerial runners are used or 739 work-hours if dug shoots are used). Total work-hour requirements for planting without anchors attached are 377 work-hours for aerial runners or 294 work-hours for dug shoots. These estimates include only onsite work and do not include travel, gear preparation, additional safety requirements for personnel, equipment, or maintenance.

91. To continue the example of planting 1 acre of manatee grass, the work-hour requirements for collection, fabrication, and planting are computed below.

Collection of aerial runners

$45,665 \div 500$/work hour = 91 work hour(s)

Collection of dug shoots

$45,665 \div 3000$/work hour = 15 work-hour(s)

Fabrication (only if PU's are attached to anchors)

$45,665 \div 100$/work hour = 456 work-hour(s)

Planting

$45,665 \div 150$/work hour = 304 work-hour(s)

92. As stated in the preceding paragraph, total work-hour requirements are subject to two variables. Fabrication accounts for 456 work-hours, so as previously computed, planting in high-energy environments will be the most costly (851 work-hours if aerial runners are used or 775 work-hours if dug shoots are used). Total work-hour requirements for planting without attached anchors are 395 work-hours for aerial runners or 319 work-hours for dug shoots.

93. The planting rate for turtlegrass sprigs or seedlings using scuba-assisted workers is about 175 PU's wh^{-1} (based on timed field trials).

Continental Shelf Associates (1982) reported that turtlegrass plugs could be planted at a rate of 5 plugs work-hour^{-1} working with a four-person field team. Planting plugs requires substantially more time and is logistically difficult in deep water and under adverse conditions, such as high-current velocities and extremely coarse- or fine-textured sediments where coring is often unmanageable.

Transplant Success

94. "Success" has been used to describe many seagrass transplants, both in a positive and negative sense (Fonseca et al. 1985b). For example, a transplant may be considered successful if PU's survive and yield a shoot generation or bottom coverage rate comparable either to natural, local seagrass populations (preferable) or to literature values, or at least have a rate significantly different from zero. Any deviation in shoot generation rate from either of the two reference data sets described above can be tested statistically. Success is therefore not simply a measure of survival, but must be based on area covered by the seagrasses over time. The area covered is only the area where rhizomes overlap, not where shoots or newly established PU's exist solitarily.

95. The persistence of transplant coverage at a given site is generally the most favored criterion for success. However, the length of time a transplant remains does not technically determine the efficacy of the technique, success of transplanting at that site, or of transplanting in general. In actuality, since we have no way of accurately predicting catastrophic climatic events, any chosen time period used to measure success must be considered arbitrary.

96. It is important, however, to sustain a seagrass planting if sediment stabilization and biological habitat development are to be achieved. This is especially true if the transplant operation is in mitigation for a long-standing natural meadow that has been destroyed. Mitigation plans may have a time requirement for unassisted endurance of a transplant. The authors recommend 3 years. This ensures that a transplanter will deliver a product, but also prevents a transplanter from attempting to replant a chronically perturbed site every few years in perpetuity even though it may have fallen within the site evaluation guidelines at the time. Continual subsidy of a site to maintain coverage does not constitute actual mitigation because the natural meadow that was destroyed did not require subsidy, unless the

transplanter wishes to assume perpetual care of the site. Success may then be defined as an initial measure of survival of PU's, area covered by those plantings and, finally, the persistence of that area covered over time.

PART V: SUMMARY AND CONCLUSIONS

97. Study sites were selected in the northeast Gulf of Mexico and south Florida to examine the shoot generation and coverage rates of the seagrasses shoalgrass, manatee grass and turtlegrass. These sites were selected to provide replicate transplants of these seagrasses across a broad geographic area and under different environmental conditions. The environmental factors considered were temperature, salinity, light and depth, hydraulic regime, sediment type, fluctuation and depth, and biotic disturbance. During the growth season at the northeast Gulf sites, only biotic disturbance was considered to be a significant factor in transplant mortality. In the south Florida sites, there were indications of temperature, light, sediment, fluctuation and depth, and biotic influences on transplant survival and growth. The influence of these factors varied between sites and season.

98. As part of the examination of seagrass population growth, natural seagrass recruitment was evaluated at all sites and was found to be insignificant. Our data collection therefore centered on recording the shoot generation and coverage rates by measuring randomly selected planting units in various study locations over time. For the three species examined, shoot generation and coverage rates were ranked shoalgrass > manatee grass > turtlegrass. Shoot generation rates of shoalgrass and manatee grass were markedly lower at the northeast Gulf sites compared with the south Florida sites, while turtlegrass has initially not shown any difference between the north and south study sites. Variation in growth rates was detectable between planting seasons even in south Florida, suggesting that optimal results could be obtained by spring plantings across the latitudinal ranges that were studied. Between-site variation in shoot generation rates was also substantial and was due to the different environmental conditions to which the transplants were exposed. The range in these rates demonstrated the kind of variability that can be expected in employing transplanting technology.

99. The large difference in shoot generation rates between seagrass species provides a basis for managing restoration projects. The relatively high shoot generation and coverage rates of shoalgrass and manatee grass make these species the best selections for transplanting. If turtlegrass is desired, this species may be added in low-density plantings to the shoalgrass/manatee grass meadow after it is established. Otherwise, attempting to establish the slower growing turtlegrass as the primary species

in a transplant may be 30 to 90 times more labor intensive than using the other species in a similar period of time.

100. Selection of transplanting stock varies with species. For shoalgrass and manatee grass, collection of stoloniferous growth or wrack-line accumulations of shoot-rhizome complexes (with rhizome apical meristems) is recommended. Harvest from natural meadows should be done as a salvage operation or from relatively quiescent areas to prevent erosion of the remaining meadow. Turtlegrass transplanting stock should be in the form of cultured, wrack-line, or natural meadow seedlings. If these are not available, then vegetative sprigs or plugs of vegetative material may be used. Harvest of vegetative material should be a salvage operation with harvest from natural meadows a last resort. Apical meristem densities in natural turtlegrass meadows often exceed 150 m^{-2}, so collection impact can be minimized. Replanting of dug areas in turtlegrass meadows with faster growing shoalgrass and manatee grass is recommended.

101. It was concluded that shoalgrass and manatee grass should be used as primary transplant species, followed by turtlegrass, on the basis of shoot generation rates. Those plantings should be considered successful if surviving planting units exhibit a coverage rate similar to data presented here for the appropriate geographic area. The extent and persistence of that coverage through time should be regarded as the final measure of success of the mitigation effort.

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Table 1

Planting Sites, Northeast Gulf, April 1984

Site Name	Figure 1 Referenced Location	Figure 8 Letter	Species (source)*,**	Dimensions for Plots
Redfish	A	B	Shoalgrass (nat. freq.)	(1) 4 x 19 m
	A	B	Manatee grass (term.)	(1) 4 x 19 m
Treasure Island	B	A	Shoalgrass (nat. freq.)	(1) 9 x 9 m
	B	A	Manatee grass (term.)	(1) 9 x 9 m

* Planting stock collected based on the number of apical meristems on the rhizomes. Natural frequency (nat. freq.) indicates no culling was made, while terminal (term.) indicates only rhizomes with apical meristems were used.

** At each site, 100 PU's were planted at a spacing of 1 m.

Table 2

Summary of Light Data and Bathymetry Information at Northeast Gulf Transplant Sites

Location	k*	Bathymetry, Z**,m	% PAR*** at Bottom
Redfish	1.69	-0.81	25.0
Treasure Island	2.26	-0.55	29.0

* Attenuation coefficient; average during study period.
** Average depth during study period.
*** Photosynthetically active radiation.

Table 3

Surface Sediment of Northeast Gulf Transplant Sites

Month (1984)	M (mean particle size)	So (sorting)	Sk (skewness)	Ki (kurtosis)	% OM (organic matter)	% S-C (silt-clay)
			Redfish			
April	2.16	0.46	-0.07	1.01	0.31	< 0.1
June	1.81	0.38	-0.08	1.06	0.27	< 0.1
			Treasure Island			
April	2.17	0.48	-0.16	1.10	0.35	< 0.1
June	2.11	0.43	-0.16	1.13	0.37	< 0.1

Table 4

Planting Sites, South Florida

Site Name	Figure 2 Referenced Location	Date Planted (month/year)	Figure 8 Letter	Species (source)*	Planting Units (PU)	Dimensions for Plots (grids)
Rock Harbor	A	Jun 83	G	shoalgrass (nat. freq.)	100	9x9 m
		Jun 83	F	shoalgrass (term.)	100	9x9 m
		Jun 83	-	shoalgrass (term)	290**	9x9 m
		Jun 83	G	manatee grass (nat. freq.)	100	9x9 m
		Jun 83	F	manatee grass (term.)	100	9x9 m
		Apr 84	-	turtlegrass (seedlings)	40	(2) 2x10 m
Channel 5	B	Feb 83	D	shoalgrass (term.)	100	9x9 m
		Feb 83	D	manatee grass (term.)	100	9x9 m
		Feb 83	-	turtlegrass (term.)	100	9x9 m
		Jun 83	E	shoalgrass (term.)	50	2x24 m
		Jun 83	E	manatee grass (term.)	50	2x24 m

(Continued)

* Planting stock was collected based on the number of apical meristems on the rhizomes. Natural frequency (nat. freq.) indicates no culling was made, while terminal (term.) indicates that rhizomes with apical meristems were used.

** Planted with spacing of 0.5 m; for all others, PU spacing was 1 m.

Table 4 (Concluded)

Site Name	Figure 2 Referenced Location	Date Planted (month/year)	Figure 8 Letter	Species (source)*	Planting Units (PU)	Dimensions for Plots (grids)
Boog Powell Marina	C	Feb 83	A	shoalgrass (term.)	100	9x9 m
		Feb 83	A	manatee grass (term.)	100	9x9 m
		Feb 83	A	turtlegrass (term.)	100	9x9 m
		Jun 83	C	shoalgrass (nat. freq.)	100	9x9 m
		Jun 83	B	shoalgrass (term.)	100	9x9 m
		Jun 83	-	shoalgrass (term.)	290**	9x9 m
		Jun 83	C	manatee grass (nat. freq.)	100	9x9 m
		Jun 83	B	manatee grass (term.)	100	9x9 m
		Apr 84	-	turtlegrass (seedlings)	40	(2) 2x10m
Stock Island	D	Feb 83	H	shoalgrass (term.)	100	9x9 m
		Feb 83	H	manatee grass (term.)	100	8x8 m
		Feb 83	C	turtlegrass (term.)	90	9x9 m

Table 5

Summary of Light Data and Bathymetry Information at South Florida Transplant Sites

Location	k*	Bathymetry, Z**,m	% PAR*** at Bottom
Rock Harbor	1.20	-0.74	41.0
Channel 5	0.20	-0.68	87.3
Boog Powell	0.65	-1.22	45.2
Stock Island	1.93	-0.71	25.4

* Attenuation coefficient during study period.
** Average depth during period.
*** Photosynthetically active radiation.

Table 6

Surface Sediment of South Florida Transplant Sites

Date	% S-C (silt-clay)	% OM (organic matter)
	Rock Harbor	
Jun 83	78.07	7.4
Nov 83	61.52	4.95
	Channel 5	
Feb 83	8.17	4.01
Jul 83	20.18	3.02
	Boog Powell	
Feb 83	64.88	4.16
Nov 83	40.62	2.63
Feb 84	28.36	2.56
	Stock Island	
	Qualitative assessment: High OM content (>5%) and high S-C content (>75%). Foot travel encountered shin-deep penetration.	

Table 7

Regression Equations for Shoot Generation of All Experimental Transplant Treatments: Northeast Gulf (Panama City), April 1984

ln no. shoots PU^{-1} = (species used)	m Slope	(d) Days	+ b y-intercept	r	Treatment* (stock source)**	Location (figure and letter referenced)
shoalgrass	0.00420	(d)	2.7295	0.2322	LE,nf	1B
	0.00353	(d)	2.4641	0.2133	LE,nf	1A
Combined	0.00415	(d)	2.5691	0.2365		
manatee grass	0.00315	(d)	1.7707	0.3788	LE,T	1B
	-0.000532	(d)	1.8154	-0.0695	LE,T	1A
Combined	0.0015	(d)	1.7862	0.1830		
turtlegrass (see Table 9)						

NOTE: Regression data are presented in Figure 8.

* All transplants at this site were made in a low-energy environment.

** LE = low-energy environment; nf = PU's assembled with unculled stock, a natural frequency of terminal meristems; T = only plants with rhizome apical meristems were used.

Table 8

Survival of Planting Units as of October* 1983
Transplant Sites in South Florida

Location (figure reference)	Species (planting environment**)	Date Planted	Percent Surviving
Rock Harbor (Figure 2a)	manatee grass (T)	Jun 83	100
	shoalgrass (nf)	Jun 83	100
	manatee grass (T)	Jun 83	100
	manatee grass (nf)	Jun 83	100
Channel 5 (Figure 2b)	shoalgrass (T)	Feb 83	~10
	shoalgrass (T)	Jun 83	~60
	manatee grass (T)	Feb 83	9
	manatee grass (T)	Jun 83	48
	turtlegrass (T)	Feb 83	0
Boog Powell (Figure 2c)	shoalgrass (T)	Feb 83	100
	shoalgrass (T)	Jun 83	100
	shoalgrass (nf)	Jun 83	100
	manatee grass (T)	Feb 83	100
	manatee grass (T)	Jun 83	100
	manatee grass (T)	Jun 83	100 (27 Jun 83)
	turtlegrass (T)	Feb 83	88 (27 Jun 83)
Stock Island (Figure 2d)	shoalgrass (T)	Feb 83	59$^{\tau}$ (29 Jun 83)
	manatee grass (T)	Feb 83	19$^{\tau}$ (29 Jun 83)
	turtlegrass (T)	Feb 83	36$^{\tau}$ (27 Jun 83)

* Unless noted otherwise.

** T = only plants with rhizome apical meristems were used, nf = PU's assembled with unculled stock, a natural frequency of terminal meristems.

τ By August, only a few remained of each. These were harvested. Average number of shoots PU^{-1} was so low that counting was discontinued. Mean number of shoots PU^{-1} was 26, 9, and 4 for the three species, respectively, after 6 months of growth at this site.

Table 9

Regression Equations for All Shoot Generation Experimental Transplant Treatments: South Florida*

ln no. shoots PU^{-1} (species used)	m = Slope	(d) Days	+ b y-intercept	r	Date Planted	Treatment: Stock** Source	Treatment: Planting Environment	Location (Reference figure and letter)
shoalgrass	0.00613	(d)	2.5297	0.4217	Feb 83	LE,T	LE	2C
uncoalesced	0.02703	(d)	1.8819	0.8728	Jun 83	LE,T	LE	2C
	0.03785	(d)	1.0988	0.8620	Jun 83	LE,nf	LE	2C
	0.00202	(d)	2.5297	0.1915	Feb 83	LE,T	HE	2B
	0.03030	(d)	1.7715	0.8721	Jun 83	LE,T	HE	2B
	0.04657	(d)	1.5540	0.9410	Jun 83	LE,T	LE	2A
	0.04336	(d)	1.2112	0.9086	Jun 83	LE,nf	LE	2A
	0.00801	(d)	1.9224	0.5276	Feb 83	LE,T	LE	2D
Combined	0.02584	(d)	1.8776	0.7186				
shoalgrass	0.00966	(d)	2.5357	0.9496	Feb 83	LE,T	LE	2C
coalesced	0.01166	(d)	2.6498	0.8598	Jun 83	LE,T	LE	2C
	0.01238	(d)	2.4349	0.7783	Jun 83	LE,nf	LE	2C
	0.02524	(d)	2.0433	0.8350	Feb 83	LE,T	HE	2B
	0.03030	(d)	1.7715	0.8721	Jun 83	LE,T	HE	2B
	0.01724	(d)	2.9393	0.7888	Jun 83	LE,T	LE	2A
	0.01157	(d)	2.9477	0.6247	Jun 83	LE,nf	LE	2A
	0.00801	(d)	1.9224	0.5276	Feb 83	LE,T	LE	2D
Combined	0.01199	(d)	2.5622	0.7732				

(continued)

* Turtlegrass is for all Florida sites (NE Gulf and S. Florida).

** LE = low energy site; HE = high-energy site; nf = PU's assembled with unculled stock, a natural frequency of terminal meristems; T = only plants with rhizome apical meristems were used.

Table 9 (Concluded)

ln no. shoots PU^{-1} (species used)	m = Slope	(d) Days	+ b y-intercept	r	Date Planted	Treatment: Stock** Source	Treatment: Planting Environment	Location (Reference figure and letter)
manatee grass uncoalesced	0.00787	(d)	2.2102	0.7069	Feb 83	LE,T	LE	2C
	0.00754	(d)	1.8713	0.5407	Jun 83	LE,T	LE	2C
	0.01547	(d)	1.2447	0.7728	Jun 83	LE,nf	LE	2C
	0.01708	(d)	1.5674	0.7250	Feb 83	LE,T	HE	2B
	0.00516	(d)	1.7824	0.6067	Jun 83	LE,T	HE	2B
	0.01491	(d)	1.6599	0.7266	Jun 83	LE,T	LE	2A
	0.02114	(d)	1.6715	0.7604	Jun 83	LE,nf	LE	2A
	0.00434	(d)	1.5438	0.3925	Feb 83	LE,T	LE	2D
Combined	0.00766	(d)	1.8504	0.5271				
manatee grass coalesced	0.00782	(d)	2.2833	0.8820	Feb 83	LE,T	LE	2C
	0.00600	(d)	2.0090	0.6257	Jun 83	LE,T	LE	2C
	0.01098	(d)	1.5906	0.9047	Jun 83	LE,nf	LE	2C
	0.01708	(d)	1.5674	0.7250	Feb 83	LE,T	HE	2B
	0.00516	(d)	1.7824	0.6067	Jun 83	LE,T	HE	2B
	0.01415	(d)	1.8255	0.8986	Jun 83	LE,T	LE	2A
	0.00913	(d)	2.2548	0.6942	Jun 83	LE,nf	LE	2A
	0.00434	(d)	1.5438	0.3925	Feb 83	LE,T	LE	2D
Combined	0.00884	(d)	1.8520	0.7531				
turtlegrass	0.00271	(d)	1.0437	0.7490	Feb 83	LE,T	LE	2C
	0.0	(d)	1.2348	0.0	Feb 83	LE,T	HE	2B
	0.00241	(d)	0.9302	0.3418	Feb 83	LE,T	LE	2D
	-0.00174	(d)	1.3863	-0.1356	Apr 84	LE,T	LE	1B
	-0.00037	(d)	1.3863	-0.0169	Apr 84	LE,T	LE	1A
Combined	0.00274	(d)	1.0143	-0.6985				

Table 10

Survey of the Numerical Abundance of Rhizome Apical Meristems of Turtlegrass at Two Stations in Florida Bay

Date	Location	Estimated Rhizome Apical Meristems, m^{-2}
3 Dec 82	Cross Bank	227
26 Dec 83	Cross Bank	74
14 May 83	Cross Bank	204
23 Jun 83	Cross Bank	159
8 Aug 83	Cross Bank	227
22 Nov 83	Cross Bank	187
24 Jul 84	Rabbit Key Basin	312

Table 11

Planting Arrangement Data for Shoalgrass (Hw) and Manatee grass (Sf)

Expected Days to Coverage	Y Value (m^2) for Each Geographic Location			
	Northeast Gulf		South Florida	
	(Hw)	(Sf)	(Hw)	(Sf)
50	-	-	0.0311	0.0307
75	0.0261	0.0146	0.2168	0.0500
100	0.0536	0.0265	0.4026	0.0693
125	0.0811	0.0384	0.5883	0.0886
150	0.1086	0.0503	0.7741	0.1080
175	0.1361	0.0622	0.8890	0.1273
200	0.1636	0.0741	1.6318	0.1466

END

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